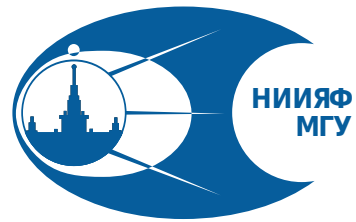
Overview of MC generators in ATLAS

used for B-physics and Onia studies

Semen Turchikhin
on behalf of the ATLAS collaboration

Skobeltsyn Institute of Nuclear Physics
Lomonosov Moscow State University



LHC Heavy Flavour Working Group public meeting

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Outline

- Overview of what generators we use for B-physics
  - HF production
  - HF decays
- Certain challenges and issues
  - particle properties consistency

HF production (1)

Baseline approach

- Standard generator for B-physics in ATLAS is PYTHIA 8
  - Version 8.186, now moving to 8.210
  - Use A14 tune with CTEQ6L1 PDF (reference: ATL-PHYS-PUB-2014-021)
- LCG installation of PYTHIA is used
  - `/afs/cern.ch/sw/lcg/external/MCGenerators_lcgcmt67c/pythia8/210/`
- Additional interface for HF production:
  - Generate full set of hard QCD processes (`HardQCD:all`)
  - The events with $b\bar{b}$ pair are selected
  - Once a $b\bar{b}$ passes user's preselection cuts, hardonise that event a few times
  - (Ensuring the fraction of events with cloned HQ kinematics is negligible)
- Substantially speeds up the generation
- $+$ handy user selection routines

HF production (2)

More special cases

- Normally NLO generators are not used for full-chain MC production
  - E.g. B^+ x-section measurement (JHEP 10 (2013) 042):
  - PYTHIA 6 was used for the signal sample full-chain production
    - Acceptances, efficiencies, fit models etc.
  - To compare with theory, NLO generators samples are used to produce particle-level MC
    - POWHEG + PYTHIA
    - MC@NLO + HERWIG
- POWHEG (matched to PYTHIA) used in some non-$b\bar{b}$ production samples
  - e.g. $H \to J/\psi\gamma$ and $Z \to J/\psi\gamma$
- $B_c^{\pm}$ production
  - dedicated PYTHIA user-process for $gg \to B_c^+ + b + \bar{c}$ modelling
  - (see e.g. references in $B_c^+ \to J/\psi D_s^{(*)+}$ analysis arXiv:1507.07099)

HF Decays

- **Either:** leave all decays to PYTHIA
  - Simple and unified treatment
  - Just a simple phase-space decay (almost) everywhere
    - impose specific angular distributions by weighting or accept-reject approach
- **Or:** use EVTGEN
  - Use LCG installation, version 1.2, 1.4 being validated
    - `/afs/cern.ch/sw/lcg/external/MCGenerators_lcgcmt67b/evtgen/1.2.0/`
  - Works as an "after-burner":
    - Takes full HepMC tree and rewrites the HF decays
  - `DEC` file is managed by ATLAS

- Radiative corrections modelled by PHOTOS++
  - Version 3.56 in LCG
    - `/afs/cern.ch/sw/lcg/external/MCGenerators_lcgcmt67b/photos++/3.56/`
  - Either interfaced to PYTHIA (if it's used standalone)
  - Or running within EVTGEN

(Some) EvtGen use-cases

- $B^+ \to J/\psi(\mu^+\mu^-)K^+$ and similar modes:
  - `SVS` and `VLL` models not requiring parameters
  - Get proper angular behaviour automatically
  - $B^+ \to J/\psi\pi^+$, $B_c^+ \to J/\psi\pi^+$ are generated similarly
- Semileptonic decay samples for dimuon background studies
  - $B^0 \to \pi^-\mu^+\nu_\mu$, $B_s^0 \to K^-\mu^+\nu_\mu$
  - `ISGW2` model to get proper shapes
- Samples for semileptonic (e.g. $K^{*0}\mu^+\mu^-$) final state studies
  - $B^0 \to K^{*0}\mu^+\mu^-$ – with flat angles (`PHSP`) and SM angles (`BTOSLLBALL`)
  - $B^0 \to J/\psi K^{*0}$ – flat angles (`PHSP`) and `SVV_HELAMP` (amplitudes from an earlier measurement)
  - $\Lambda_b \to \Lambda(1520)\mu^+\mu^-$, $\Lambda_b \to pK^-\mu^+\mu^-$ – no dedicated models available, use `PHSP`
- Samples for $B_c^+ \to J/\psi D_s^{(*)+}$ analysis
  - $B_c^+ \to J/\psi(\mu^+\mu^-)D_s^+$ with $D_s^+ \to \phi\pi^+$, $\phi \to K^+K^-$: `SVS`, `VLL`, `VSS` models
  - $B_c^+ \to J/\psi D_s^{*+}$: `SVV_HELAMP` model, 3 individual samples for each helicity component
    - used for the measurement of their relative contributions

Issues (1)

Consistency of particle properties between generators

- By design, PYTHIA and EVTGEN use different particle data
  - masses, lifetimes, decay modes, Breit–Wigner shape treatment
- Examples of possible problematic cases
  - B^+ can be produced either by PYTHIA or by EVTGEN having decayed and excited B state
    - Two different masses in the two cases!
    - In principle, such situation could even lead to energy conservation problems
  - K^* may have different treatment of Breit–Wigner shape in different generators
    - Some are produced in HF decays $\rightarrow$ decayed by EVTGEN
    - Others are from prompt processes $\rightarrow$ handled by PYTHIA (default)
    - Inconsistent behaviour between HF production and underlying event

Issues (2)

- For **exclusive** samples we usually can tune signal particle properties if needed
  - However, problems may still appear in the opposite b decay tree
- More complicated for **inclusive** samples
  - They are normally larger and more expensive to redo
  - Currently don't use EvtGen for early B-physics inclusive J/ψ samples
- b hadron properties should be *consistent across all groups* in ATLAS
  - In ATLAS numerous samples containing b-jets are produced for variety of high energy studies
  - ATLAS MC group coordinates usage of Generators to make sure B properties are consistent over all ATLAS studies
  - A typical MC campaign may last $\sim$ *a few months*, we can't change the particle properties too often

Summary

- Current baseline: PYTHIA 8
- Use EVTGEN where it's beneficial and does not produce issues (i.e. case-by-case basis)
  - PHOTOS is on by default
- LCG installations are used for these generators
- Other generators – on case-by-case basis

Backup slides